

# Outpatient Course and Complications Associated With Home Oxygen Therapy for Mild Bronchiolitis

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## KEY WORDS

bronchiolitis, oxygen, emergency department

## ABBREVIATIONS

DH—Denver Health

ED—emergency department

IQR—interquartile range

RAD—reactive airways disease

Dr Flett conceptualized and designed the study, extracted data from patient charts, performed exploratory analysis, and drafted the initial manuscript; Ms Breslin participated in the study design, performed the primary data analysis, oversaw the exploratory analysis, and reviewed the final manuscript; Dr Braun provided data on patients discharged before 2006 and critically reviewed the manuscript; Dr Hambidge designed the study, extracted data from patient charts, oversaw all statistical analysis including the final model selection and exploratory analysis, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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**WHAT'S KNOWN ON THIS SUBJECT:** Home oxygen has been safely incorporated into emergency department management of bronchiolitis in certain populations. After discharge, a small proportion of patients (2.7%–6%) require subsequent admission. For patients managed successfully as outpatients, pediatricians report variable practice styles and comfort levels.



**WHAT THIS STUDY ADDS:** Our results define the clinical course and outpatient burden associated with discharge on home oxygen. By using an integrated health care system, we captured slightly higher rates (9.4%) of subsequent admission and found fever to be associated with this outcome.

## abstract

**BACKGROUND:** Home oxygen has been incorporated into the emergency department management of bronchiolitis in high-altitude settings. However, the outpatient course on oxygen therapy and factors associated with subsequent admission have not been fully defined.

**METHODS:** We conducted a retrospective cohort study in consecutive patients discharged on home oxygen from the pediatric emergency department at Denver Health Medical Center from 2003 to 2009. The integration of inpatient and outpatient care at our study institution allowed comprehensive assessment of follow-up rates, outpatient visits, time on oxygen, and subsequent admission. Admitted and nonadmitted patients were compared by using a  $\chi^2$  test and multivariable logistic regression.

**RESULTS:** We identified 234 unique visits with adequate follow-up for inclusion. The median age was 10 months (interquartile range [IQR]: 7–14 months). Eighty-three percent of patients were followed up within 24 hours and 94% within 48 hours. The median length of oxygen use was 6 days (IQR: 4–9 days), and the median number of associated encounters was 3 (range: 0–9; IQR: 2–3). Ninety-three percent of patients were on room air at 14 days. Twenty-two patients (9.4%) required subsequent admission. Fever at the initial visit ( $>38.0^\circ\text{C}$ ) was associated with admission ( $P < .02$ ) but had a positive predictive value of 15.4%. Age, prematurity, respiratory rate, oxygen saturation, and history of previous bronchiolitis or wheeze were not associated with admission.

**CONCLUSIONS:** There is a significant outpatient burden associated with home oxygen use. Although fever was associated with admission, we were unable to identify predictors that could modify current protocols. *Pediatrics* 2014;133:769–775

Over the past decade, home oxygen therapy has been incorporated into the management of bronchiolitis in certain populations.<sup>1-4</sup> Hypoxia complicates 70% to 84% of bronchiolitis admissions, prolonging hospital stay by 1.6 days and representing the leading barrier to discharge.<sup>5-7</sup> Small changes in oxygen level have a significant impact on decisions to admit, suggesting that pulse oximetry could drive increased admissions in the face of stable mortality rates.<sup>8-10</sup>

Pediatric hospitals located at high altitudes see a high proportion of hypoxic children with bronchiolitis. In Denver, Colorado, 37% of cases seen in the emergency department (ED) are started on oxygen.<sup>2</sup> To address the associated overcrowding, guidelines have been developed to discharge children with mild illness on home oxygen. This practice has been associated with reduced admission rates, lower hospital cost, and high parental satisfaction.<sup>1,2,4</sup> Children discharged on oxygen are typically seen within 24 hours at an outpatient clinic, an established respiratory care center, or an ED.<sup>1,4</sup> Still, outpatient management of home oxygen is variable and there is little information on expected course.<sup>11</sup> Although previous studies have evaluated length of oxygen therapy by survey, none have directly reviewed outpatient records associated with oxygen use.<sup>1,11</sup> Furthermore, a small percentage of discharged children require subsequent admission, and although previous work has examined the overall safety of home oxygen therapy, there are few data on factors associated with subsequent hospitalization.<sup>1,2,4</sup>

In this context, we aimed to define the outpatient course of children on oxygen for bronchiolitis and identify characteristics associated with subsequent admission. In a cohort of children discharged from the ED on oxygen for

bronchiolitis, we determined rates of follow-up, length of oxygen therapy, and number of clinic visits associated with oxygen use. We then compared children who required subsequent admission with nonadmitted children, focusing on characteristics that could identify them at the time of initial discharge.

## METHODS

We conducted a retrospective cohort study in children diagnosed with bronchiolitis and discharged on home oxygen from the ED from January 2003 to December 2009. The study was approved by the Colorado Multiple Institutional Review Board.

### Study Setting and Discharge Protocol

Our study included the Pediatric Urgent Care Center and the Denver Emergency Center for Children, both affiliated with Denver Health (DH), an integrated safety net health system with a tertiary medical center and 8 outpatient clinics linked by a shared electronic medical record. Patients insured through the system, including 40% of Denver's children, receive nearly all outpatient, inpatient, and emergency care within DH.<sup>12,13</sup> The majority of children at DH have Medicaid insurance, with no difference in out-of-pocket cost for families seen in a primary care clinic, urgent care, or emergency care. A small number of privately insured patients (6% in 2012) incur higher copayment costs at the Pediatric Urgent Care Center and Denver Emergency Center for Children.

In 2003, our institution implemented an ED guideline for home oxygen use in mildly hypoxic children with bronchiolitis (Table 1). Discharge criteria are based on results of clinical trials conducted at similar altitude settings (1600 m).<sup>1</sup> Apnea is considered a contraindication to discharge. Eligible children are given instructions by

**TABLE 1** Criteria for Discharge on Home Oxygen for Mild Bronchiolitis

1. Meets all inclusion criteria
<ul style="list-style-type: none"> <li>• Upper airway infection associated with wheezing ± crackles</li> <li>• Age 2 months to 2 years (at least 44 weeks' gestational age)</li> <li>• First time wheezing</li> <li>• ED visit between December and April</li> <li>• Secretions manageable with bulb suctioning by caregivers</li> <li>• Smoke-free home environment</li> <li>• Reliable family with access to emergency medical care</li> <li>• Lives at an altitude ≤6000 feet</li> </ul>
2. No identified exclusion criteria
<ul style="list-style-type: none"> <li>• Toxic appearance or evidence of bacterial disease</li> <li>• Apparent life-threatening event occurring with illness</li> <li>• Cardiac, chronic lung, or neuromuscular disease</li> <li>• Oxygen requirement at baseline</li> <li>• Immunodeficiency</li> </ul>
3. Clinical evidence of mild illness after suctioning, oxygen, and observation for >4 hours
<ul style="list-style-type: none"> <li>• Alert, active, and feeding well</li> <li>• None to minimal retractions</li> <li>• Respiratory rate &lt;50 breaths/minute</li> <li>• Adequate oxygenation (~90%) on ≤0.5 L/minute of oxygen</li> </ul>

a respiratory therapist, provided with a portable oxygen tank to last 24 hours, and instructed to call the home oxygen company after discharge to deliver a larger, in-home supply. Patients are instructed to follow-up with their primary care provider within 24 hours, or if unable to be seen, to return to the ED within this time frame. Oxygen discontinuation has no formal guidelines. Clinical staff typically stop the oxygen in clinic and monitor respiratory rate, work of breathing, and room air saturations for 20 minutes. If normal, the order to discontinue home oxygen therapy is given.

### Study Population

We included children aged 0 to 36 months who were discharged from the ED on home oxygen for bronchiolitis from 2003 to 2009. We included children outside the recommended age guidelines of 2 to 24 months to capture

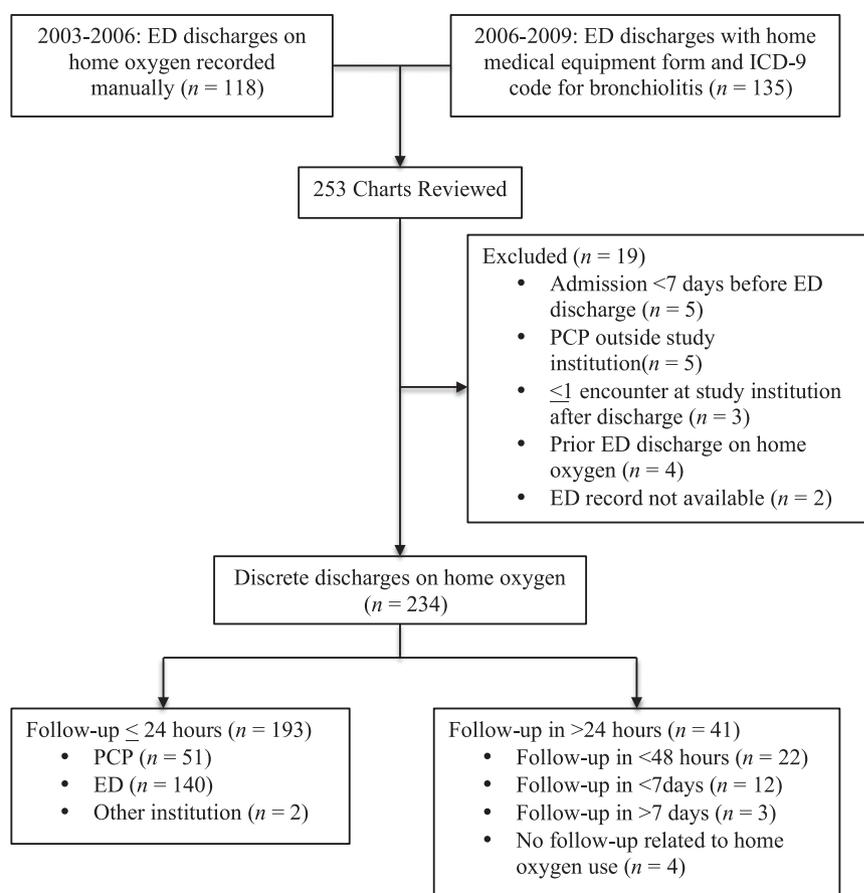
practice variability. Children were identified from 2003 to 2006 by a manual list of all home oxygen discharges and from 2006 to 2009 by the International Classification of Diseases, Ninth Revision, code for bronchiolitis (466.1) and a unique home health form.

Our exclusion criteria are shown in Fig 1. We excluded children with primary care outside the study institution who would not be expected to have inpatient or outpatient records to assess for subsequent admission. We presumed that children with private pediatricians might return for an oxygen check the following day but would not have additional visits at our institution. Therefore, we identified these children by notation of private pediatrician or by  $\leq 1$  visit to the study institution after discharge from the ED. For children with multiple episodes of bronchiolitis requiring home oxygen, we included only the first discharge in our analysis.

### Chart Review

We reviewed ED and outpatient records from day of oxygen initiation to last clinic visit associated with oxygen use or date of subsequent admission. Sociodemographic characteristics were extracted from an administrative database. Clinical characteristics were recorded from the electronic medical record directly into an Excel spreadsheet (Microsoft Corporation, Redmond, WA). From the initial ED visit, we recorded respiratory rate, oxygen saturation on room air, amount of oxygen at discharge, fever ( $\geq 38^{\circ}\text{C}$ ), diagnosis of pneumonia, diagnosis of reactive airways disease (RAD), and discharge on scheduled albuterol. If referred directly from the clinic while on oxygen, we reviewed these notes for fever and, if all ED measurements were on oxygen, for room air saturation.

We reviewed inpatient records for respiratory, cardiac, immunologic, and



**FIGURE 1**

Cohort assembly and follow-up of children with bronchiolitis discharged on oxygen. ICD-9, International Classification of Diseases, Ninth Revision; PCP, primary care provider.

developmental conditions. Gestational age was categorized as  $\geq 37$  weeks when documented as “full term.” For children on oxygen  $>1$  week, we reviewed all visits for 2 years after discharge to identify unusual conditions associated with extended oxygen use.

Outpatient or ED visits “associated with oxygen” included visits with the child on oxygen and rechecks of oxygen saturation within 24 hours of oxygen discontinuation. Date of discontinuation was based on (1) the date of an order to discontinue oxygen, (2) the date on which the patient had an oxygen saturation  $>90\%$  on room air and oxygen use was recommended “as needed,” or (3) the date on which oxygen was stopped by the parent, as indicated in the primary care provider’s

clinic notes. Transition to nighttime use was considered continued oxygen therapy.

### Data Analysis

Continuous variables were evaluated by means or medians depending on normality and dichotomized on the basis of their distribution. To analyze factors associated with subsequent admission, variables with  $P < .2$  on  $\chi^2$  testing were selected for entry into a multivariable logistic regression model. Exploratory analysis of factors associated with greater length of oxygen therapy was performed by linear regression without selection parameters. Data were analyzed with SAS Enterprise 4.3 or SAS 9.3 (SAS Institute, Cary, NC), with  $P < .05$  considered to be significant.

## RESULTS

### Patient Characteristics

From 2003 to 2009, 253 unique children were discharged from the ED on home oxygen for bronchiolitis and 234 were included in our final analysis (Fig 1). Clinical and sociodemographic characteristics are listed in Table 2. The median age at discharge was 10 months (range: 2–31 months; interquartile range [IQR]: 7–14 months). Five children were 24 to 36 months old. Ten (4.3%) children had a gestational age <35 weeks. Our study population included 11 children (4.7%) with a previous diagnosis of RAD, 35 children (15%) with previous bronchiolitis, and 43 children (18.4%) with 1 or both

diagnoses in the past. One child had selective immunoglobulin A deficiency.

Thirty-six children (15.4%) were given a nebulizer treatment in the ED. Eight children (3.4%) were discharged with a diagnosis of RAD or scheduled albuterol use. Seven children (3.0%) were diagnosed with pneumonia before discharge. Whereas most children (99.1%) were discharged on  $\leq 0.5$  L/minute of oxygen on the basis of institutional guidelines, 2 children were discharged on 1 L/minute of oxygen. These children met all other criteria for discharge and had an unremarkable outpatient course with 5 to 8 days on oxygen. Seven children (3.0%) had a reported problem with oxygen delivery, including failure of delivery and

broken components. One of these children required subsequent admission.

### Rates of Follow-up

Follow-up rates for the total study population are shown in Fig 1. ED visits accounted for 72.5% of visits within 24 hours and 37.0% of all follow-up visits. Four children (1.7%) had no recorded visits until after oxygen had been discontinued by their parent. These children were seen later for unrelated clinic visits and had no noted complications related to their bronchiolitis.

### Outpatient Course Without Subsequent Admission

Two hundred twelve (90.6%) children were managed exclusively with home oxygen. These children had a median of 3 (range: 0–9; IQR: 2–3) outpatient or ED visits associated with oxygen use. The median length of use was 6 days (range: 1–425 days; IQR: 4–9 days), with 65.5% of children discontinuing oxygen by 7 days and 93.3% of children discontinuing oxygen by 14 days. Eleven children required oxygen for 15 to 22 days. One child required oxygen for 39 days. Finally, a 3-month-old infant remained on oxygen for 425 days and was later diagnosed with interstitial lung disease.

In exploratory analysis, the length of oxygen therapy was significantly associated with age <6 months ( $P < .001$ ) and gestational age <37 weeks ( $P < .001$ ). These associations remained significant when the child on oxygen for 425 days was excluded from analysis. The median length of oxygen therapy in children <6 months old was 9 days (range: 1–425 days; IQR: 4–11 days) compared with 6 days in children aged 6 to 18 months and 5 days in children >18 months old. Length of therapy was not associated with age >18 months, language, amount of oxygen at ED discharge, or history of previous wheeze.

**TABLE 2** Characteristics of Children Discharged on Home Oxygen

Characteristic	Total (n = 234), n (%)	Not Admitted (n = 212), n (%)	Subsequently Admitted (n = 22), n (%)	P
Age				.88
<6 months	30 (12.8)	27 (12.7)	3 (13.6)	
6–18 months	175 (74.8)	158 (74.5)	17 (77.3)	
>18 months	29 (12.4)	27 (12.7)	2 (9.1)	
Gender				.79
Female	102 (43.6)	93 (43.9)	9 (40.9)	
Male	132 (56.4)	119 (56.1)	13 (59.1)	
Language				.21
Non-English	98 (41.9)	86 (40.6)	12 (54.5)	
English	136 (58.1)	126 (59.4)	10 (45.5)	
Race/ethnicity				.19
Hispanic	132 (56.4)	116 (54.7)	16 (72.7)	
White	65 (27.7)	60 (28.3)	5 (22.7)	
Other	37 (15.8)	36 (17.0)	1 (4.5)	
Gestational age				.996
30–36 weeks	32 (13.7)	29 (13.7)	3 (13.6)	
$\geq 37$ weeks	202 (86.3)	183 (86.3)	19 (86.4)	
Highest respiratory rate				.46
$\geq 60$ breaths/minute	79 (33.8)	70 (33.0)	9 (40.9)	
<60 breaths/minute	155 (66.2)	142 (67.0)	13 (59.1)	
Highest respiratory rate				.07
$\geq 70$ breaths/minute	26 (11.1)	21 (9.9)	5 (22.7)	
<70 breaths/minute	208 (88.9)	191 (90.1)	17 (77.3)	
Lowest O <sub>2</sub> saturation				.39
<85%	57 (24.4)	50 (23.6)	7 (31.8)	
$\geq 85%$	177 (75.6)	162 (69.2)	15 (68.1)	
Lowest O <sub>2</sub> saturation				.31
<80%	11 (4.7)	9 (4.2)	2 (9.1)	
$\geq 80%$	223 (95.3)	203 (95.8)	20 (90.9)	
Amount of O <sub>2</sub>				.06
0.5 or 1 L/minute	148 (63.2)	130 (61.3)	18 (81.8)	
0.125 or 0.25 L/minute	86 (36.8)	82 (38.7)	4 (18.2)	
Previous wheeze or bronchiolitis	43 (18.4)	39 (18.4)	4 (18.2)	.98
Fever ( $\geq 38.0^\circ\text{C}$ )	117 (50.0)	99 (46.7)	18 (81.8)	.002

## Factors Associated With Subsequent Admission

After discharge on home oxygen, 22 of 234 children (9.4%) were admitted. Four of these children were admitted to hospitals outside the study institution but had notation of their admission in later clinic notes. All admitted children were seen within 24 hours of initial discharge. Nineteen of 22 (86.4%) were admitted at that time, and 3 were admitted 2 to 5 days after discharge. Reasons for admission included increased work of breathing or respiratory rate (72.7%), increased oxygen requirement (45.4%), pneumonia (22.7%), intravenous fluids (4.5%), parental concern (4.5%), and failure of oxygen delivery (4.5%). The 15 children initially diagnosed with RAD or pneumonia did not require subsequent admission. No admitted children died, required intensive care, or needed positive-pressure ventilation. One 7-month-old infant, with a gestational age of 30 weeks, experienced 2 apneic events that required deep suctioning for secretions.

Sociodemographic characteristics were not associated with subsequent admission (Table 2). Of the characteristics selected into the multivariable model, fever at initial visit was associated with admission (odds ratio: 4.17; 95% confidence interval: 1.29–13.42,  $P < .02$ ) (Table 3). The final model had a good fit and was robust in sensitivity analysis. Half of our population had fever and 47% of febrile patients were not admitted, yielding a positive predictive value of 15.4% and a negative predictive value of 96.6% within our sample.

## DISCUSSION

This is the first study, to our knowledge, to systematically evaluate the outpatient course of children managed with home oxygen for bronchiolitis. We

**TABLE 3** Multivariable Analysis for Hospital Admission After Initial Discharge on Oxygen

Characteristic	OR (95% CI)
Fever ( $\geq 38^\circ\text{C}$ )	4.17 (1.29–13.42)
Amount of $\text{O}_2 \geq 0.5$ L/minute	2.49 (0.79–7.85)
Race	
Hispanic versus white	1.0 (0.32–3.09)
Hispanic versus other	0.20 (0.02–1.62)
Highest respiratory rate $>70$ breaths/minute	2.37 (0.72–7.80)

CI, confidence interval; OR, odds ratio.

found that the majority of children attend recommended follow-up within 24 to 48 hours, require a median of 3 follow-up visits related to oxygen use, and spend a median of 6 days on oxygen. A small percentage of patients (9.4%) require admission after initial discharge but cannot be easily identified by clinical or demographic characteristics.

The protocol at our study institution is similar to local and regional protocols.<sup>2,4</sup> Children in our study were slightly older (median age: 10 months; IQR: 7–14 months) than those previously reported in Denver (mean age:  $8.5 \pm 4.4$  months) and Utah (median age: 6 months; IQR: 2–11 months).<sup>2,4</sup> This difference may reflect our age guidelines for 2 to 24 months compared with previous studies that evaluated children aged 2 to 18 months.<sup>1,2,4</sup> Our results did not find age  $>18$  months to be associated with subsequent admission, but inference is limited by the small sample size of this group ( $n = 29$ ).

Our population had relatively mild hypoxemia, although nearly 30% of children had at least 1 arterial oxygen saturation measurement of  $<85\%$ . Eighteen percent of children had previous wheeze or bronchiolitis without increased odds of subsequent admission. Whereas previous wheeze, as a marker for RAD, is often an exclusion criterion for home oxygen therapy, our results may reflect the difficulty in differentiating RAD from viral-associated wheezing in this age group

and suggest that this population could be considered for home oxygen therapy.<sup>14</sup>

After discharge, children required a median of 3 (IQR: 2–3) primary care or ED visits for home oxygen use. These results are concordant with the median of 2 visits reported by physicians managing home oxygen therapy and emphasize the need for outpatient resources when implementing home oxygen therapy.<sup>11</sup> There are varied approaches to address this need.<sup>1,3,4</sup> Because our institution represents an urban safety net health system with busy primary care clinics, the pediatric ED serves as an overflow mechanism for patients to be seen within 24 hours of discharge. Whereas this structure produces a high proportion of ED follow-up visits, patients without private insurance (94%) incur the same cost for an ED visit related to home oxygen as for a clinic visit.

Our median length of oxygen use, 6 days (IQR: 4–9 days), is similar to the median reported by surveyed pediatricians.<sup>11</sup> However, in our study, 66% of children discontinued oxygen at 1 week, compared with a previous study in which 89% reported discontinuing oxygen at 1 week.<sup>1</sup> Compared with this study, our study population was slightly older with similar to slightly higher oxygen saturations, failing to explain the discrepancy in length of oxygen therapy. It is possible that this difference reflects our inclusion of nighttime oxygen use, or that more routine use of home oxygen for bronchiolitis has been affected by busy clinics, with appointments spaced farther apart, when compared with the environment of a clinical trial. Although we did not evaluate symptom duration before home oxygen, our results agree with the expected length of illness for bronchiolitis (12–15 days).<sup>15,16</sup> Furthermore, our findings that 93% and 99% of patients are on room air at 14 and 22 days, respectively, may support the referral of patients who

require oxygen for >3 weeks. Exploratory analysis suggests that length of oxygen therapy could be associated with younger age and prematurity, but given our limited model this possibility requires further study.

Our study setting allowed us to evaluate outpatient course within a closed system and under “real world” conditions where follow-up is recommended but not arranged. Most patients discharged from our study institution represent low-income and/or non-English-speaking populations who could face particular barriers to follow-up care. Still, we found that 84% of patients were seen within 24 hours and 94% were seen within 48 hours of discharge. Bajaj et al<sup>1</sup> arranged follow-up for patients enrolled in their clinical trial, reporting that 89% completed phone follow-up at 72 hours and 89% had a survey completed by their primary care provider within 48 hours. Compared with follow-up rates for common childhood illnesses (45%) and asthma (12%–55%), our rates are markedly higher.<sup>17–21</sup> These results could reflect the inclusion of “reliable family” as a discharge criterion (Table 1) or could represent the unique systems that facilitate follow-up for patients on home oxygen.

With our access to inpatient, emergency, and outpatient records, we were able to capture events outside the expected course. We identified low numbers of caregivers who did not follow-up within 1 week (1.4%), who discontinued their child’s oxygen without primary care provider follow-up (1.7%), or who experienced mechanical or logistical complications of home oxygen delivery and use (3%), including

1 child admitted after her oxygen was not delivered. Previous studies have identified “problem with oxygen delivery” as a reason for admission but have not been able to capture children without initial follow-up or with parental discontinuation of oxygen.<sup>1,2</sup>

In our study, 22 patients (9%) were subsequently admitted after initial ED discharge. Previous studies have reported lower rates in children discharged on home oxygen (2.7%–6%) and in comparable populations of children discharged on room air (4%).<sup>1,2,4</sup> Compared with these studies, our study population was slightly older, with similar to higher oxygen saturation, similar reasons for subsequent admission, and similarly uneventful hospital course.<sup>1,2,4</sup> The difference in admission rates could reflect higher capture of admissions in an integrated health care system. In fact, 4 of the 22 children were admitted to hospitals outside of the study institution and identified only by chart review of later outpatient visits.

Although we confirmed that a small proportion of children require subsequent admission, we were unable to find factors that could identify this population and modify current discharge guidelines. Fever at initial visit was associated with admission and had a high negative predictive value (96.6%), but its high prevalence and low positive predictive value (15.4%) limit clinical utility. Previous studies in bronchiolitis without home oxygen have similarly failed to identify predictors for subsequent admission, with the exception of age <2 months.<sup>22,23</sup>

Our study has limitations. Information was collected from an integrated health

care system in 1 city and may not be generalizable to other settings. Whereas viral testing is done when clinically indicated, routine testing is not performed. As a result, we could not evaluate the impact of viral etiology.<sup>24</sup> We also did not collect information on length of illness and could not incorporate this variable into our exploratory analysis on length of oxygen use. Finally, our results may be specific to high-altitude settings. Whereas the majority of studies on home oxygen for bronchiolitis have been conducted at high altitudes, Tie et al<sup>3</sup> evaluated its use at sea level, discharging patients after 24 hours of inpatient observation and using an intensive schedule of home visits. More studies evaluating illness severity and hypoxia in children with bronchiolitis at lower altitudes are needed to explore its feasibility in this setting and to establish the appropriate parameters.

## CONCLUSIONS

Our results reveal that home oxygen can be feasibly integrated into ED care for bronchiolitis in a primarily Medicaid population with good adherence to recommended follow-up. A small percentage of children required subsequent admission but could not be identified by clinical factors at initial presentation. There is significant outpatient demand associated with home oxygen use, requiring mechanisms for follow-up or expanded clinic availability. Future programs will have to address these needs before implementation.

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